U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE
SUBCOMMITTEE ON ENERGY

HEARING CHARTER

The Plug-in Hybrid Electric Vehicle Act of 2006 (Discussion Draft)

Wednesday, May 17 2006
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

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1. Purpose

On Wednesday, May 17, 2006, the Energy Subcommittee of the House Committee on Science will hold a hearing on a discussion draft of legislation to promote research and development (R&D) on plug-in hybrid electric vehicles and related advanced-vehicle technologies.

2. Witnesses

- **Mr. Roger Duncan** is the Deputy General Manager of Austin Energy in Texas and serves on the board of the Electric Drive Transportation Association.
- **Dr. Mark Duvall** is a Technology Development Manager for Electric Transportation & Specialty Vehicles in the Electric Power Research Institute's (EPRI) Science & Technology Division. He currently oversees EPRI's Grid-Connected Hybrid Electric Vehicle Working Group and is EPRI's technical lead for the DaimlerChrysler-EPRI Plug-in Hybrid Electric Sprinter Van Program. EPRI is the research arm of the U.S. electric utility industry.
- **Dr. Andrew Frank** is a professor in the Mechanical and Aeronautical Engineering Department at The University of California, Davis, and the Director of the UC Davis Hybrid Electric Vehicle Research Center.
- **Mr. John German** is Manager of Environmental and Energy Analyses for American Honda Motor Company. Mr. German is the author of a variety of technical papers and a book on hybrid gasoline-electric vehicles published by the Society of Automotive Engineers.
- **Dr. Cliff Ricketts** is a professor of Agricultural Education in the School of Agribusiness and Agriscience at Middle Tennessee State University. Dr. Ricketts has designed and built engines powered from a variety of sources including ethanol, methane, soybean oil, and hydrogen.
- **Dr. Danilo Santini** is a Senior Economist in the Energy Systems Division of Argonne National Laboratory's Center for Transportation Research, as well as a former Chair of the Alternative Fuels Committee of the National Academy of Sciences' Transportation Research Board.

3. Overarching Questions

The hearing will address the following overarching questions:

1. What major research, development, and demonstration work remains on plug-in hybrid electric vehicle technologies? How should this work be prioritized?
2. What are the largest obstacles facing the widespread commercial application of plug-in hybrid electric vehicles and what steps need to be taken to address these hurdles? (batteries, infrastructure, consumer preference, automotive inertia, cost-competitiveness, etc.)
3. How does the federal government support the development of plug-in hybrid electric vehicle technologies? What can the federal government do to accelerate the development and deployment of plug-in hybrid electric vehicles?
4. Does the discussion draft of the Plug-In Hybrid Vehicle Act of 2006 address the most significant technical barriers to the widespread adoption of plug-in hybrid electric vehicles?

4. Brief Overview

- Hybrid vehicles, such as the Toyota Prius or the Ford Escape, combine batteries and an electric motor, along with a gasoline engine, to improve vehicle performance in city driving conditions and to reduce gasoline consumption.

- Plug-in hybrid vehicles are a more advanced version of today's hybrid vehicles. They involve larger batteries and the ability to charge those batteries overnight using an ordinary electric outlet.

- Unlike today's hybrids, plug-in hybrids are designed to be able to drive for extended periods solely on battery power, thus moving energy consumption from the gasoline tank to the electric grid (batteries are charged overnight from the grid) and emissions from the tailpipe to the power plant (where, in theory, they are more easily controlled).

- Plug-in hybrids could significantly reduce U.S. gasoline consumption because most daily trips would be powered by a battery. The potential for oil savings is related to the length of time, or the distance, that a plug-in hybrid can travel solely on battery power.

- President Bush, as part of his *Advanced Energy Initiative*, has established the goal of developing technology that would enable plug-in hybrids to travel up to 40 miles on battery power alone. Plug-in hybrids that could operate for 40 miles on an overnight charge from the electrical grid could offer significant oil savings because most Americans commute less than 40 miles a day. The electricity used to charge the batteries overnight would be generated from domestic sources (only 3 percent of the electricity used in the United States is generated from oil) and that electricity would primarily be consumed at night when demand is low.

- Plug-in hybrids could benefit consumers because of their greater fuel economy and the relatively low cost of energy from the electric grid. Fuel economy in hybrid vehicles is related to the degree to which engine load can be carried by the electric motor (powered by batteries). Because plug-in hybrids have large batteries and are designed to operate for an extended period on battery power alone, they offer the potential of significantly greater fuel economy. Some proponents of plug-in hybrids claim that consumers will be able to recharge their batteries overnight at gasoline-equivalent cost of $1 per gallon.[1]

- While plug-in hybrid vehicles offer many advantages, a number of technical barriers must be overcome to enable their development and widespread commercial application. Although specialty conversion kits are available (in very limited quantities and at high cost) to upgrade an ordinary hybrid to a plug-in hybrid, many component technologies, particularly battery technology, must be advanced before plug-in hybrids can be made available to consumers, at mass-market scale, and at reasonable cost and reliability. R&D is needed to increase the reliability and durability of batteries, to significantly extend their lifetimes, and to reduce their size and weight.

- In May 2006, Mr. Smith of Texas prepared a discussion draft of legislation to conduct research and development (R&D) on advanced plug-in hybrid vehicle technologies and to demonstrate plug-in hybrid vehicles so as to promote their commercial application in the consumer marketplace. (A section-by-section analysis of the bill is included later in this charter.)

5. Background

How would plug-in hybrid vehicles differ from today's hybrid vehicles? Plug-in hybrid vehicles would have a much bigger battery and motor, and thus could offset even more gasoline consumption than hybrids do by using more electric power. Unlike today's hybrid vehicles, the battery of a plug-in hybrid would be charged while parked using a standard 120-volt electrical outlet. (Additional technical information is available in the technical appendix to this charter.)

How would plug-in hybrid vehicles promote energy independence? Plug-in hybrids could greatly decrease the need for petroleum by shifting the energy supply for vehicles from the gasoline pump to the electrical grid. Since only 3 percent of petroleum is used to generate electricity (a figure unlikely to increase due to poor economics associated with electricity from oil), an expansion in plug-in hybrids would help decrease U.S. dependence on imported oil. Because of their greater ability to operate on electric power, plug-in hybrids have the potential for significantly greater fuel economy than currently-available hybrid vehicles. An entrepreneurial group in California (CalCars) has experimented with plug-in hybrids and claims to have achieved fuel economy in excess of 100 miles per gallon after converting a standard hybrid vehicle to a plug-in hybrid.

How would plug-in hybrid vehicles affect the grid? Plug-in hybrids typically would be used during the daytime, when people commute to work or when businesses are making deliveries, and charged overnight, when the grid is running well below its peak load. The increased demand for electricity during overnight charging also would provide a load leveling effect—idle generating capacity would be brought into productive use during off-peak hours. Allowing plants to operate with less

[1] Plug-in Partners website. Date accessed – May 12, 2006. See http://www.pluginpartners.org/plugInHybrids/economicBenefits.cfm

variability and closer to optimum output could enhance the overall efficiency of the electrical system.

How would plug-in hybrid vehicles affect emissions? Plug-in hybrids shift much of the emissions from the tailpipe to the power plant. Proponents claim that the overall emissions level of the most common pollutants is lower from plug-in hybrids than from standard automobiles, even accounting for emissions at the power plant. The one exception is sulfur dioxide emissions in areas that utilize a great deal of coal-fired electricity.

Widespread use of plug-in hybrids would enable metropolitan areas suffering from high air pollution concentrations during morning and evening commutes to shift those emissions away from city centers and to nighttime hours. This shift would reduce the exposure of high population density areas to harmful ozone levels and other tailpipe pollutants. Greenhouse gas levels could also be reduced, depending on the mix of energy sources used to generate electricity.

What does the President's budget include for plug-in hybrid R&D? The President's fiscal year 2007 (FY07) budget submission requests $12 million for R&D on plug-in hybrid vehicles, including an increase of $6 million for R&D related to advanced battery development. The President's FY07 request also includes $51 million for R&D on related vehicle technologies, including advanced power electronics, simulation and validation, and vehicle test & evaluation.

Addition details on the difference between plug-in hybrids and today's hybrids, along with details on the technical barriers to developing mass-market plug-in hybrid vehicles, are given in the technical appendix (section 8) of this charter.

A description of Mr. Smith's discussion draft, as provided to the witnesses, is given below. The language describing the demonstration program in the discussion draft has been modified since it was sent to the witnesses.

6. Section-by-Section Description of the Discussion Draft

Sec. 1. Short Title.

The Plug-in Hybrid Electric Vehicle Act of 2006.

Sec. 2. Near Term Vehicle Technology Program

a. Definitions.

Defines terms used in the text.

b. Program.

Requires the Secretary of Energy to carry out a program of research, development, demonstration, and commercial application for plug-in hybrid electric vehicles and electric drive transportation technology.

Requires the Secretary of Energy to ensure that the research program is designed to develop

- high capacity, high efficiency batteries with:
    - improved battery life, energy storage capacity, and power discharge;
    - enhanced manufacturability; and
    - the minimization of waste and hazardous material production throughout the entire value chain, including after the end of the useful life of the batteries
- high efficiency onboard and offboard charging components;
- high power drive train systems for passenger and commercial vehicles and for non-road equipment;
- control systems, power trains, and systems integration for all types of hybrid electric vehicles, including:
    - development of efficient cooling systems; and
    - research and development of control systems that minimize the emissions profile of plug-in hybrid drive systems
- a nationwide public awareness strategy for electric drive transportation technologies that provide teaching materials and support for university education focused on electric drive systems and component engineering.

c. Goals.

Requires the Secretary of Energy to ensure that the program develops projects, in partnership with industry and institutions of higher education, which are focused on:

- innovative electric drive technology developed in the United States;
- growth of employment in the United States in electric drive design and manufacturing;
- clarification of the plug-in hybrid potential through fleet demonstrations; and
- acceleration of fuel cell commercial application through comprehensive development and demonstration of electric drive technology systems

d. Demonstration and Commercial Application Program.

Requires the Secretary of Energy to develop a program of demonstration and commercial application for plug-in hybrid electric vehicles and flexible fuel plug-in hybrid electric vehicles.

Requires the Secretary of Energy to award grants under this program on a competitive basis, but give preference to applications that are matched with state or local funds.

Requires that grants awarded by the Secretary do not exceed the annual maximum per-vehicle amounts as follows:

Annual Maximum Grant per Vehicle

FY07 – FY09	FY10 – FY12	FY13	FY14	FY15	FY16
$10,000	$8,000	$6,000	$3,000	$2,000	$1,000

e. Merit based federal investments.

Requires the Department of Energy to ensure that the funding for the activities in this section are awarded consistent with the merit based guidelines for federal investments established in *The Energy Policy Act of 2005* (EPACT) (P.L. 109-58).

f. Authorization of Appropriations.

Authorizes appropriations to the Secretary of Energy of $200 million for each of fiscal years 2007 through 2016 to carry out the program of research, development, demonstration, and commercial application for plug-in hybrid electric vehicles and electric drive transportation technology.

Authorizes appropriations to the Secretary of Energy of $50 million for each of fiscal years 2007 through 2016 to carry out the demonstration of plug-in hybrid electric vehicles and flexible-fuel plug-in hybrid electric vehicles.

Sec. 3. Lightweight Materials Research & Development.

a. In General.

Requires the Secretary of Energy to create a lightweight materials research and development program. The program will focus on materials (for both light and heavy duty vehicles) that will reduce vehicle weight and increase fuel economy while maintaining safety. In addition, the program will investigate ways to reduce the cost and enhance the manufacturability of lightweight materials used in making vehicles.

b. Authorization of Appropriations.

Authorizes appropriations to the Secretary of Energy of $50 million for each of fiscal years 2007 through 2012 to carry out this section.

7. <u>Witness Questions</u>

In the letters inviting them to the hearing, each of the witnesses was asked to address the following questions in his testimony:

- What major research, development, and demonstration work remains on plug-in hybrid electric vehicle technologies? How should this work be prioritized?
- What are the largest obstacles facing the widespread commercialization of plug-in hybrid electric vehicles and what steps need to be taken to address these hurdles? (batteries, infrastructure, consumer preference, automotive inertia, cost-competitiveness, etc.)
- How does the federal government support the development of plug-in hybrid electric vehicle technologies? What can the federal government do to accelerate the development and deployment of plug-in hybrid electric vehicles?
- Does the discussion draft address the most significant technical barriers to the widespread adoption of plug-in hybrid electric vehicles?

8. Technical Appendix

What are the technological differences between plug-in hybrid vehicles and the hybrid vehicles on the road today?

The hybrid vehicles on the road today leverage the battery and electric motor at certain peak demand points during the drive cycle of the vehicle. The battery, generally nickel metal hydride (NiMH) technology, is replenished by occasionally transferring energy from the engine as well as from recovering energy expended in braking the vehicle (i.e., regenerative braking). The battery maintains a state of charge within a fairly narrow band, never gaining or losing a great deal of energy; this is known as shallow cycling or a "sustained charge" approach. Using the energy from NiMH battery to avoid gasoline consumption helps hybrid vehicles achieve increased fuel economy.

Plug-in hybrid vehicles take advantage of the same fuel economy principle, only the goal is to use a better battery to avoid even greater amounts of gasoline. Lithium-ion (Li-ion) battery technology has been identified as the most promising candidate for plug-in hybrid electric vehicles. Li-ion batteries have greater energy density than NiMH batteries and greater power discharge, characteristics that would allow a vehicle to travel further using less gasoline and offer better performance than one with a NiMH battery.

In addition, plug-in hybrid electric vehicles could offer long ranges of electric-only operation (also known as a "ZEV" range or Zero Emissions Vehicle range). This attribute is particularly desirable in congested metropolitan areas. If today's hybrid vehicles with a NiMH battery were available with an electric-only operation mode, they would be capable of only a 1-2 mile ZEV range. In comparison, experts familiar with battery technology claim that Li-ion batteries could achieve ZEV ranges of 20, 40, or even 60 miles.

It is not clear whether plug-in hybrid vehicles would be manufactured with an option of driving in "electric-only" mode. Regardless, the overwhelming majority of the energy used in city driving would stem from the battery, given that the engine is inefficient in stop-and-go traffic. Thus, the long ZEV range figures associated with Li-ion batteries not only indicate the large quantity of electrical energy they contain, but also the potential to drive lengthy distances under city conditions using mostly electrical energy. With Americans commuting an average of 20-30 miles roundtrip each day, the plug-in hybrid vehicle with a Li-ion battery could greatly reduce petroleum consumption.

Why don't we use lithium-ion battery technology today given its benefits?

Li-ion batteries are not a new technology. They are used in cell phones and laptop computers. Scaling up Li-ion batteries for use in automobiles, however, is new territory and presents new challenges. Experts in the field estimate that the cost of Li-ion batteries is two to four times above the level needed to be commercially viable. Cost reductions are needed in the areas of raw materials and processing, as well as cell and module packaging.

In addition, it is not clear if Li-ion batteries are capable of lasting 15 years, the average life of a vehicle. This issue is compounded by the fact that plug-in hybrid vehicles would use deep cycling, which shortens the life of the battery, over the course of its drive cycle. Unlike the sustained charge approach used in today's hybrid vehicles, the profile of plug-in hybrid is much different. Plug-in hybrids would start the day at nearly 100 percent state of charge (SOC), having been charged overnight. To minimize use of gasoline, the battery would be depleted over the course of the day until the SOC reached about 20 percent; fully depleting the battery each day would severely limit its lifetime. At a SOC of about 20 percent, the plug-in hybrid would act like a hybrid vehicle and proceed with a "sustained charge" approach until the vehicle could be fully recharged again. Further testing is needed to determine whether Li-ion batteries could last the life of the vehicle under this combined deep/shallow cycling.

Additional R&D is needed in other areas as well. There is uncertainly about the ability of Li-ion batteries to handle abuse and improper maintenance, such as crushing the battery or overcharging. Current Li-ion batteries require mechanical and electronic devices for protection against these abuses. Likewise, more work is needed to enhance Li-ion technology in colder temperatures. Under these conditions, Li-ion demonstrates a reduction in its ability to discharge power and its lack of tolerance for handling surges from regenerative braking. In addition, thermal management issues will need to be addressed, as long periods of continuous battery use can lead to a build up of heat. There are existing technologies that can be used that tolerate higher temperatures, but they would increase the cost of the battery.

What challenges inhibit the near term introduction of plug-in hybrid electric vehicles?

As noted earlier, the battery technology for plug-in hybrids is not yet cost-competitive. Since the battery represents a large proportion of the incremental cost of plug-in hybrid over a conventional vehicle, R&D will likely be focused here. The issue of cost is further complicated by the deep discharges that are used in plug-in hybrids. If batteries do not last the lifetime of the vehicle, replacement batteries will make the plug-in hybrids even less attractive from a cost standpoint. The cost of a plug-in hybrid passenger vehicle with a 20 mile ZEV is approximately $4,500 to $6,100 more than a conventional vehicle of comparable size, according to a 2002 report by the Electric Power Research Institute.

Major manufacturers of today's hybrids have exerted a great deal of effort to educate consumers that hybrid vehicles differ from all-electric vehicles of the past in that they do not need to be plugged in. The plug-in hybrid would be a new technology, also using the word "hybrid" in its label, but will require customers to plug into an electrical outlet in their home or garage. Even if customers understand this distinction, they may not be willing or able to conform to a new norm. Plug-in hybrids may provide the convenience of reducing the number of trips to gas stations, but consumers must become comfortable with and accustomed to the idea of plugging in their vehicle. Other customers may be interested in plug-in hybrids, but currently may live in a dwelling without a plug-in infrastructure or otherwise not conducive to vehicle charging. Responding to all of these challenges will likely require outreach and education.